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STATUS OF MAJOR POTATO DISEASES AND FARMER PERCEPTIONS IN RWANDA

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ABSTRACT

Potato (*Solanum tuberosum* L.) is an important food and cash crop in most sub-Saharan (SSA) countries. Despite its popularity and surging demand, particularly among urban dwellers, potato production is generally low and decreasing in SSA, owing in part to various devastating diseases. This study aimed at assessing the intensity and distribution of major potato diseases on farms in major potato growing regions in Rwanda. A total of 120 samples of tubers and symptomatic leaves were collected from three districts, located at different altitudes, namely Kayonza (1443 - 1672 m.a.s.l), Nyamagabe (1824 - 2193 m.a.s.l) and Nyabihu (2209- 2696 m.a.s.l). The samples were used to identify and assess prevalence of diseases. Data on perceptions were collected on 148 potato farmers from the same districts, using a semi-structured questionnaire. Bacterial wilt was the most potato farmers damaging disease in the low and medium elevations, estimated at > 50% of the responders. On the other hand, late blight and viruses were the most prevalent in high elevation areas, estimated at 42 and 44% of respondents, respectively. The severity and incidence of viruses (PVS, PVX and PVY) and bacterial wilt were the most severe at the lowest elevation; but lowest at the highest elevation. Potato viruses, especially PVS, PVX and PVY; and bacterial wilt and late blight were confirmed to be the major potato diseases in Rwanda.

Key Words: Bacterial wilt, *Ralstonia solanacearum,* viruses

RÉSUMÉ

La pomme de terre (*Solanum tuberosum* L.) est une importante culture vivrière et commerciale dans la plupart des pays d'Afrique subsaharienne (ASS). Malgré sa popularité et sa forte demande, notamment parmi les citadins, la production de pomme de terre est généralement faible en ASS, en partie à cause de diverses maladies dévastatrices. Cette étude visait à évaluer l'intensité et la répartition des principales maladies de la pomme de terre dans les exploitations agricoles des principales régions productrices de pomme de terre au Rwanda. Au total, 120 échantillons de tubercules et de feuilles symptomatiques ont été collectés dans trois districts, situés à différentes altitudes, à savoir Kayonza (1443 - 1672 metres d'altitude), Nyamagabe (1824 - 2193 metres d'altitude) et Nyabihu (2209 - 2696 metres d'altitude). Les échantillons ont été utilisés pour identifier et évaluer la prévalence des maladies. Des données sur les perceptions ont été collectées auprès de 148 producteurs de pommes de terre des mêmes districts, à l'aide d'un questionnaire semi-structuré. Le flétrissement bactérien était la maladie la plus dévastatrice pour les producteurs de pommes de terre dans les zones de basse et moyenne altitude, estimée à plus de 50 % des répondants. En revanche, le mildiou et les virus étaient les plus répandus dans les zones de haute altitude, estimés respectivement à 42 et 44 % des répondants. La gravité et l'incidence des virus (PVS, PVX et PVY) et du flétrissement bactérien étaient les plus graves à l'altitude la plus basse, mais les plus faibles à l'altitude la plus élevée. Les virus de la pomme de terre, en particulier PVS, PVX et PVY, ainsi que le flétrissement bactérien et le mildiou se sont avérés être les principales maladies de la pomme de terre au Rwanda.

Mots Clés: flétrissement bactérien, *Ralstonia solanacearum*, virus

INTRODUCTION

Potato (*Solanum tuberosum* L.) is among the most important food and cash crops in sub-Saharan Africa (SSA), particularly in urban areas (Okonya and Kroschel, 2016). The crop is grown at elevations ranging from 1300 to 2600 meters above sea level (m.a.s.l.); and Eastern Africa is one of the greatest potato producer and consumer sub-regions in the SSA (Okonya and Kroschel, 2016).

Potato production in Eastern Africa is dreaded by a range of diseases, both viral and bacterial, and at different stages of growth. In Rwanda, potato yield losses attributed to diseases are in the range of 29 - 100% for late blight, caused by *the Phytophthora infestans* pathogen (Seifu, 2017); 70-100% for bacterial wilt caused by *Ralstonia solanacearum* pathogen; and up to 100% for viruses, respectively (Muhinyuza *et al*., 2012; Okonya *et al*., 2019).

Potato disease intensity is influenced by environmental conditions; often being highest at high temperatures and low altitudes; and lowest at low temperatures and highest altitudes (Forbes *et al*., 2002). It is difficult to predict the status (intensity and distribution) of these diseases presently, amidst the dynamics of climate change that has pervaded SSA in recent times. Moreover, a clear understanding of the prevalence and intensity of diseases is a pre-requisite for designing their efficacious and sustainable control measures. The objective of this study was to assess the intensity and distribution of major potato diseases on farms at different altitudes in Rwanda.

MATERIALS AND METHODS

Study area. A survey was conducted during April - May, 2021, in three major potato-growing districts in Rwandan; namely Kayonza (Eastern Plateau); Nyamagabe (Congo Nile Watershed); and Nyabihu (Birunga) (Karemangingo and Bugenimana, 2018). The study involved potato

fields belonging to households, distributed over the study districts. Table 1 presents the primary profiles of the study district and their relevant characteristics.

The field surveys. Two surveys were conducted, one for disease assessment and the other for farmer perceptions about the potato diseases status and intensity in major potato growing regions in Rwanda.

Disease assessment. A total of 120 fields (40 fields per district) were sampled for tubers and symptomatic leaves, during April - May, 2021. Disease incidence and severity; and geographical coordinates were recorded, the latter using a GPS handset. In each field, five rectangular plots of dimensions 10 plants x 5 rows, were marked in two diagonal lines (X shaped) across the field (Delp, 1986). The field sampling design adopted is illustrated in Figure 1.

In each plot, the incidence index was evaluated by calculating the proportion of affected plants, over a total number of plants (Brown and Keane, 1997). In each plot, a composite sample of leaves was taken for virus testing; and tubers for bacterial testing from at least two symptomatic potato plants.

Each affected plant was evaluated for disease severity, using a scale of 0 to 5 scores (Gopal and Singh, 2003). As for late blight, the severity scale used was: 1 = no or few blighted leaves, <3% of lesions (very low severity); 2 = 4-10% of blighted foliage (low severity); 3 = 11-30% of blighted foliage (moderate severity); 4 = 31- 60% blighted foliage (high severity); and 5 = over 60% of blighted foliage (high severity) (Gopal and Singh, 2003).

The scale used for viruses was: 0 = no symptoms (healthy plant); 1 = individual plant showing symptoms between 1-25% (low severity); 2 = plants visually affected at 26 – 51% (moderately severe); 3 = plant visually affected at 52 -75% (high severity); and 4 = plant attacked at more than 76% (very high severity) (Anjum *et al*., 2017). For bacterial wilt, the following scale was used: 1 = no symptom, 0% of wilted leaves; 2 = one or two leaves wilted (less than 20%), low severity; 3 = at least half the plant wilted (21 -50%),

TABLE 1. Biophysical characteristics of potato producing districts involved in this study

Province	District	Surveyed elevations (m.a.s.l)	Agro-ecolological zones
Eastern	Kayonza (Low elevation)	1443 – 1672	Eastern Plateau
Southern	Nyamagabe (Medium elevation)	1824 – 2193	Congo Nile Watershed Divide
Western	Nyabihu (High elevation)	2209 – 2696	Birunga

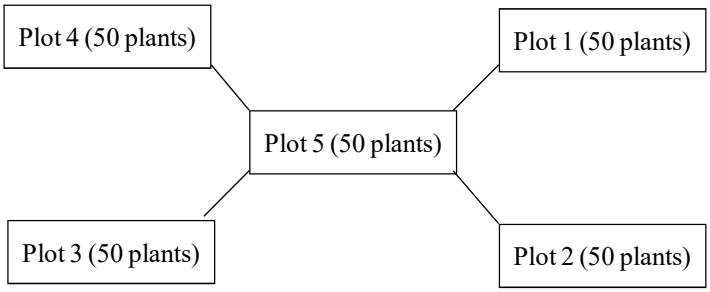

Figure 1. Sampling design used in the potato diseases field study in Rwanda.

moderate severity; 4 = most all plant wilted 51 - 75%), high severity; and 5 = more than 75% of all the plants wilted or dead, very high severity (Uwamahoro *et al.*, 2018b). Individual plot severity was estimated using the formula by Brown and Keane (1997):

$$\text{Severity Index (\%)} = \frac{\Sigma\text{class frequency x rating class}}{\Sigma\text{observations x maximal disease grade}} \times 100$$

……..……. Equation 1

Laboratory tests were performed on the samples to confirm the presence of bacterial wilt, late blight and viral diseases. NCM - ELISA (Enzyme-Linked Immunosorbent Assay on Nitrocellulose Membrane, was used to identify *Ralstonia solanacearum,* causing bacterial wilt (Priou *et al*., 1999). The DAS - ELISA (Double Antibody Sandwich-Enzyme Linked Immuno Sorbent Assay), was done to identify six most important potato viruses, which include PVY, PLRV, PVX, PVM, PVS, and PVA (Yardimci *et al*., 2015).

Farmers' perceptions. A total of 148 household heads involved potato production, were interviewed, using a semi-questionnaire to understand farmer perceptions of the significance of potato disease intensity and their distribution in potato fields in Rwanda. The number of potato farmers interviewed in Kayonza, Nyamagabe and Rubavu were 43, 55 and 50, respectively; being proportional to the total number of potato farmers per district as per the Potato Production Statistics of 2019 (National Institute of Statistics of Rwanda, 2020). Sample size was computed using Equation 2, as per Dagnelie, (1998).

$$n = \frac{1.96^2 \text{ x } (p)\,(1\text{-}p)}{d^2} \quad \text{..... Equation 2}$$

Where:

1.96 = Z value for 95% confidence limits;

p = estimated prevalence (for instance 0.3 for 30%);

(p) (1-p) = deviation for a binary variable (binomial); and

d = ½ of the desired confidence interval, for instance 0.025 for ± 5%.

The thrust of the questionnaire was restricted to issues related to potato disease occurrence and yield challenges associated with potato production in Rwanda.

Data analysis. Disease incidence and severity indices were subjected to the Shapiro-Wilk normality test, one-way ANOVA, and Kruskal-Wallis (nonparametric) tests, using "R Studio" software. Incidence and severity were considered as dependent variables; while their scores were considered as independent variables.

To test for the variation in incidence (present = yes or absent = no) in the samples across the three districts, a Chi-square ($\chi 2$) goodness of fit (GF) test was performed. Furthermore, the Chi-square ($\chi 2$) test of independence between virus statuses (present or absence), with districts (elevations) was performed. In all statistical analyses, the level of significance was tested at $P < 0.05$.

Monte Carlo Simulate and Fisher's exact tests were used to analyse questionnaire data. For all analyses, means were separated (grouped) using the Least Significant Difference (LSD) procedure at $P<0.05$ level of significance (ªahin and Aybek, 2019).

RESULTS

Disease incidence index and severity. There were significant differences ($P<0.05$) in bacterial wilt, late blight and viruses incidences, among elevations (Figs. 2 and 3). Overall, the lowest elevation (Kayonza District) had the highest incidence for all three types of diseases; followed by medium elevation (Nyamagabe), and lastly by the highest

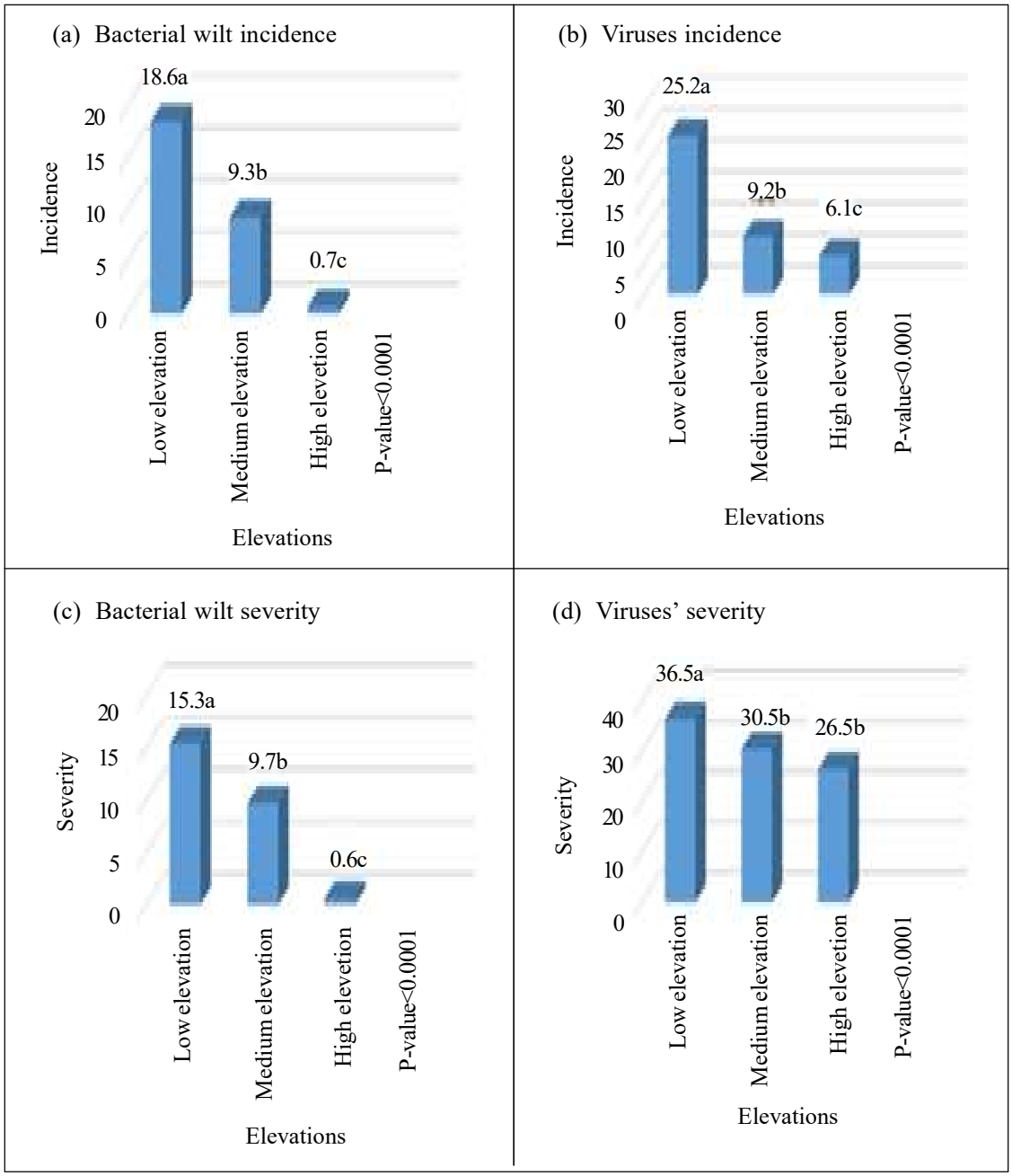

Figure 2. Incidence and severity indices for bacterial wilt: (a) incidence of bacterial wilt, (b) incidence of viruses, (c) severity of bacterial wilt and (d) severity of viruses.

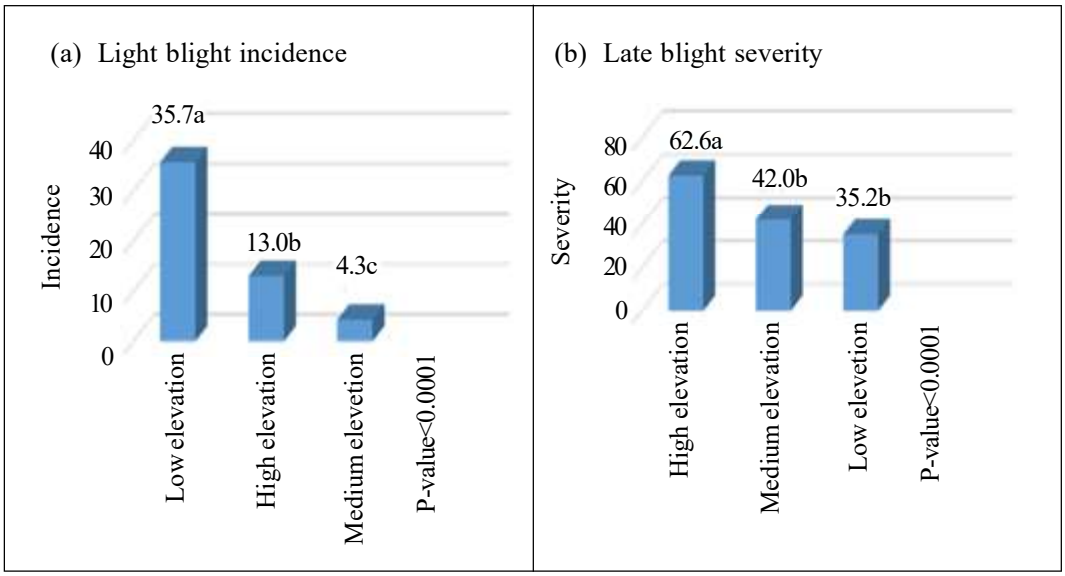

Figure 3. Late blight incidence (A) and severity (B) indexes for potato fields in Rwanda.

TABLE 2. Test of goodness of fit (GF) demonstrating virus presence in each elevation level with potato fields in Rwanda

Elevations	Virus	Number of samples	% of presence	Chi-square test of GF	P-value of χ^2 test of GF
Low	PLRV	40	27.5	0.81	0.3692
Medium	PLRV	40	32.5	4.9	0.0269
High	PLRV	40	37.5	2.5	0.1138
Low	PVA	40	40	1.6	0.2059
Medium	PVA	40	30	6.4	0.01141
High	PVA	40	37.5	2.5	0.1138
Low	PVM	40	25	10	0.0016
Medium	PVM	40	30	6.4	0.0114
High	PVM	40	32.5	4.9	0.0269
Low	PVS	40	67.5	4.9	0.0269
Medium	PVS	40	52.5	0.1	0.7518
High	PVS	40	27.5	8.1	0.0044
Low	PVX	40	60	1.6	0.2059
Medium	PVX	40	45	0.4	0.5271
High	PVX	40	25	10	0.0016
Low	PVY	40	57.5	0.9	0.3428
Medium	PVY	40	25	10	0.0016
High	PVY	40	15	19.6	<0.0001

elevation (Nyabihu District) (Figs. 2A, B and 3A). A similar scenario was noted for bacterial wilt severity results from the three elevations (Fig. 2C). For viruses, the highest severity was correspondingly found at the lowest elevation (Fig. 2D); while the highest late blight severity was inversely at the highest elevation (Fig. 3B).

Laboratory tests

Viruses. Potato leaf samples tested positive for six viruses, namely PLRV, PVX, PVM, PVS, and PVA (Table 2). However, the PLRV and PVA were absent in medium elevation (P = 0.02 and 0.01, respectively). PVM was minimal at all elevations (P = 0.002, 0. 01 and 0.03, respectively); while PVS and PVX were absent at the highest elevation (P = 0.0044 and 0.0016, respectively). PVY was the least present at both the medium and highest elevations (P = 0.002 and < 0.0001, respectively, Table 2).

Chi-square test showed independence (P > 0.05) of PLRV, PVA and PVM statuses (present = yes or absent = no) with elevation levels; while there was a strong association (P < 0.01) of the status of PVS, PVX, and PVY with them. Low elevation showed the highest prevalence of PVS, PVX, and PVY; followed by the medium elevation (Table 3)

Bacterial wilt. From the Chi-square test of goodness of fit*, Ralstonia bsolanacearum,* the cause of bacterial wilt, was highly prevalent at the lowest elevation; followed by medium and trailed by the highest elevation (Table 4). *Ralstonia* was prevalent at higher indices (P<0.0001) at the low elevation and medium elevations; than at the highest elevation. These results provide evidence of a highly association (dependence) between bacterial wilt disease and elevation levels (P < 0.01).

Farmer perceptions. Potato farmers perceived the low and medium elevations, as being the most damaged by potato bacterial wilt, followed by potato late blight (Table 5). On the other hand, viruses and potato late

TABLE 3. Contingency Table showing the dependence of potato viruses, *vis-à-vis* to elevations

Elevation	PLRV		PVA		PVM		PVS		PVX		PVY	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Low	29	11	24	16	30	10	13	27	16	24	17	23
Medium	27	13	28	12	28	12	19	21	22	18	30	10
High	25	15	25	15	27	13	29	11	30	10	34	6
P-values	χ^2=1	P=0.6	χ^2=0.9	P=0.6	χ^2=0.5	P=0.7	χ^2=13.1	P<0.1	χ^2=10.1	P=0.0	χ^2=18.0	P=0.0001

TABLE 4. Status of *Ralstonia* at different elevation levels in potato growing fields in Rwanda

Elevation	No	Yes	% yes	Chi square test of GF	P value
Low elevation	4	36	90	25.6	<0.0001
Medium	24	16	40	1.6	0.2059
High	36	4	10	25.6	<0.0001
Chi square test of GF	24.5	28	-	-	-
P value for the 2 test of goodness of fit	<0.0001	<0.0001	-	-	-

TABLE 5. Most damaging potato diseases in Rwanda

Elevation	Potato bacterial wilt (%)	Potato late blight (%)	Viruses (%)
Low	95	4.7	0
Medium	52.7	29.1	16.4
High	14	42	44
Fisher's exact test P-value		<0.0001	

TABLE 6. The second most damaging potato disease in Rwanda

Elevation	Early blight	Potato bacterial wilt	Potato late blight	Root rot	Viruses
Low	0	4.7	27.9	4.7	62.8
Medium	1.8	27.3	36.4	0	32.7
High	0	34	30	0	36
Fisher's exact test P-value			0.001074		

blight were the most damaging diseases in high elevation areas (Table 5). The three diseases (bacterial wilt, late blight and viruses) were perceived by all farmers, irrespective of altitudes, to be the most important damaging to potato production in Rwanda (Tables 5 and 6).

DISCUSSION

Disease incidence index and severity

Disease incidence. The highest prevalence of bacterial wilt and viruses incidence indices and distribution, at the lowest elevation (Kayonza District); and decreasing down the altitudes (Fig. 2) is a natural phenomenon, whereby altitude acts as a proxy for temperature, rainfall and relative activity; the aggregate of which impact disease activity. High altitudes do not favour plant disease proliferation as much as their low land counterparts. Nevertheless, this may have implications in the long run, owing to climate changes which are expected to increase temperatures both in the low and highlands, to the disadvantage of potato production. The only viable strategy against this is to invest in breeding for potato varietal resistance against these diseases (Muhinyuza, 2012).

In the present study, we noted dependence of viruses and bacterial wilt against altitudes. (Tables 3 and 4). Similar results were reported by Forbes *et al*. (2002) that potato viruses were

distributed following altitudinal gradients in Ethiopia, with higher intensity at low altitudes and the lowest intensity at the highest elevations.

It should be noted, however, that there has been a significant change in temperatures from the annual mean of 21.2, 18.3 and 12.8 °C measured in 1987, to 21.4, 19.0 and 15.8 °C in 2023, for the low land, medium and high altitudes, respectively (Rwanda Meteorological Agency, 2023). This continuous change in climatic conditions (temperature, rainfall and relative humidity) has implications on potato disease proliferation, thus calling for momentous monitoring of their (diseases) occurrence and response to management strategies.

Laboratory results. The six viruses widely recognised as the most ravaging to potato production (PLRV, PVY, PVM, PVS, PVA and PVX), were recorded in the present study (Tables 2 and 3). Viruses, PLRV and PVS, were earlier observed to be more prevalent in Rwanda; while PVY and PVX were present in 2016 (Okonya *et al*., 2021).

Farmer perceptions. The survey report that viruses and bacterial wilt were the most important and the most damaging to potato production, at all altitudes (Tables 5 and 6), was confirmed by the laboratory evaluation as well. The same diseases were observed earlier in Rwanda by different reports (Mugabo *et al*., 2018; Uwamahoro *et al.,* 2018). Potato tuber yield reductions of 70-100% have been reported in Rwanda, owing to potato late blight, bacterial wilt and viruses, when no control measures were implemented (Okonya *et al*., 2019). It is, therefore, recommended that development efforts geared towards promotion of potato production in Rwanda, should put thrust mainly on combating late blight, bacterial wilt and viruses' diseases, with particular emphasis on breeding for resistant materials, as well as extensive dissemination of available control measures.

CONCLUSION

This study has identiffied three main problematic potato diseases in Rwanda, namely bacterial wilt, late blight and viruses. This was confirmed by both laboratory and field diagnoses; and potato farmer perceptions. The diseased prevalence levels depended on elevation and levels of resistance among potato varieties. It is recommended that development efforts should put thrust mainly on combating late blight, bacterial wilt and virus diseases, with particular emphasis on breeding for resistant materials and capacity building for farmers on efficacious potato disease management focusing, with a focus on altitudinal jurisdiction idiosyncrasies.

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REFERENCES

[a]ahin, M. and Aybek, E. 2019. Jamovi: An easy to use statistical software for the social scientists. *International Journal of Assessment Tools in Education* 6(4):670-692. https://doi.org/10.21449/ijate.661803

Anjum, R., Khan, M.A., Olawale, K.O. and Baber, R. 2017. Field evaluation and enzyme-linked immunosorbent assay detection of potato leaf roll virus, potato virus X and potato virus Y in potato germplasm. *Journal of Agricultural Science* 9(7): 229. https://doi.org/10.5539/jas.v9n7p229

Brown, J. and Keane, P. 1997. Assessment of disease and effects on yield. *Plant Pathogens and Plant Diseases* 316-329.

Dagnelie, P. 1998. Statistique théorique et appliquée: Statistique descriptive et bases de l'inférence statistique (Vol. 1). De Boeck Supérieur.

Delp, B.R. 1986. Field runner: A disease incidence, severity, and spatial pattern assessment system. *Plant Disease* 70(10): 954. https://doi.org/10.1094/pd-70-954

Forbes, G.A., Grunwald, N.J., Mizubuti, E.S.G., Andrade-Piedra, J.L. and Garrett, K. A. 2002. Potato late blight in developing countries. *Organization*, *December 2015*. pp. 1-23. https://www.researchgate.net/publication/239921301_Potato_Late_Blight_in_Developing_Countries

Gopal, J. and Singh, B.P. 2003. Screening potatoes for resistance to late blight (Phytophthora infestans) under field conditions. *Potato Research* 46(1-2):47-56. https://doi.org/10.1007/bf02736102

Karemangingo, C. and Bugenimana, D.E. 2018. Productivity of irish potato varieties under increasing nitrogen fertilizer application rates in Eastern Rwanda. *African Journal of Agricultural Research*, 13(19):988-995. https://doi.org/10.5897/ajar2018.13068

Mugabo, J., Nyamwaro, S.O., Kalibwani, R., Tenywa, M.M., Buruchara, R. and Fatunbi, O. 2018. Innovation opportunities in potato production in Rwanda. *FARA Research Reports* 2(16):1-15.

Muhinyuza, J.B., Shimelis, H., Melis, R., Sibiya, J. and Nzaramba, M.N. 2012. Participatory assessment of potato production constraints and trait preferences in potato cultivar development in Rwanda. *International Journal of Development and Sustainability* 1(2):358-380. http://isdsnet.com/ijds-v1n2-23.pdf

National Institute of Statistics of Rwanda, M. of H. and T.D.P.I. 2020. Rwanda Demographic and Health Survey 2019-2020: Key indicators report. In: Demographic and Health Surveys 53(9): 163.

Okonya, J.S., Gamarra, H., Nduwayezu, A. and Bararyenya, A. 2021. Serological survey and metagenomic discovery of potato viruses in Rwanda and Burundi reveals absence of PVY in Burundi and first report of TRV in potatoes in sub Saharan Africa. *June*. https://doi.org/10.1016/j.virusres.2021.198487

Okonya, J.S. and Kroschel, J. 2016. Farmers' knowledge and perceptions of potato pests and their management in Uganda. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 117(1):87-97. https://doi.org/10.3390/agriculture6030038

Okonya, J.S., Ocimati, W., Nduwayezu, A., Kantungeko, D., Niko, N., Blomme, G., Legg, J.P. and Kroschel, J. 2019. Farmers reported pest and disease impacts on root, tuber, and banana crops and livelihoods in Rwanda and Burundi. *Sustainability (Switzerland)* 11(6):1-20. https://doi.org/10.3390/su11061592

Priou, S., Gutarra, L. and Aley, P. 1999. Highly sensitive detection of *Ralstonia solanacearum* in latently infected potato tubers by post-enrichment enzyme-linked immunosorbent assay on nitrocellulose membrane. *EPPO Bulletin* 29(1-2):117-125. https://doi.org/10.1111/j.1365-2338.1999.tb00805.x

Rwanda Meteorology Agency. 2023. Downscaled climate projections for national adaptation plan in Rwanda. May. www.rema.gov.rw 213p.

Seifu, Y.W. 2017. Reducing severity of late blight (*Phytophthora infestans*) and improving potato (*Solanum tuberosum* L.) tuber yield with pre-harvest application of calcium nutrients. *Agronomy* 7(4): 69 https://doi.org/10.3390/agronomy7040069

Uwamahoro, F., Berlin, A., Bucagu, C., Bylund, H. and Yuen, J. 2018. Potato bacterial wilt in Rwanda: Occurrence, risk factors, farmers' knowledge and attitudes. *Food Security* 10(5):1221-1235. https://doi.org/10.1007/s12571-018-0834-z

Yardýmcý, N., Çulal Kýlýç, H. and Demir, Y. 2015. Detection of PVY, PVX, PVS, PVA, and PLRV on different potato varieties in Turkey using DAS-ELISA. *Journal of Agricultural Science and Technology* 17(3):757-764.